DEPARTMENT OF DEFENSE BLOGGERS ROUNDTABLE WITH RICHARD HAMMOND, THEORETICAL PHYSICIST WITH THE ARMY RESEARCH OFFICE (VIA TELECONFERENCE FROM IRAQ) SUBJECT: INVSIBILITY RESEARCH TIME: 2:00 P.M. EDT DATE: TUESDAY, AUGUST 19, 2008

(Note: Please refer to www.dod.mil for more information.)

LINDY KYZER (U.S. Army Public Affairs.): We can go ahead and get started; I think my clock just turned to 2:00 p.m.

So, again, we are thrilled to have with us Dr. Rich Hammond. He's a theoretical physicist with the Army Research Office. He's been doing a lot of cutting-edge research. I'm sure most of you received his bio, "Negative Index Materials Research." It's in the early stages of that research, but it's very interesting and unique technology, and they're looking into ways to make light reflect in ways it never has before, with extraordinary effects.

So, with that, clearly, I'm not the expert and I will butcher this terminology the more I have to say it, so we'll go ahead and let Dr. Hammond give his remarks, then we'll go down the line in order as the folks called in. We'll let you ask questions. Just please keep to one question for the first go-around and then we should have time for follow-up as well. If you are not asking a question, we ask you to please try to keep that mute button pushed so we avoid any background noise. Again, with that, I have Dr. Richard Hammond. Go ahead and give a few remarks to start us out.

MR. HAMMOD: Thanks, Lindy. And you did a good job; you didn't butcher anything. So what I have here is three paragraphs I'll read, and then after that it will just be -- we'll just have the discussion. So here goes:

Metamaterials are artificial materials with versatile properties that can be tailored to fit almost any practical need, and thus go well beyond what can be obtained with natural materials. Recent progress in developing optical metamaterials allows unprecedented extreme control over the flow of light at both the nano and macroscopic scales. The innovative field of transformation optics, which is enabled by metamaterials, has inspired reserachers to take a fresh look at the very foundations of optics and helped create a new paradigm for the science of light. Similar to general relativity, where time and space are curved, transformation optics shows that the space for light can also be bent in an almost arbitrary way. Most importantly, the optical space can be designed and engineered, opening the fascinating possibility of controlling the flow of light with nanometer spatial precision.

This is in striking contrast to the conventional homogeneous materials where light typically propagates along a straight line. Even in a non-homogeneous conventional materials, light adheres to Fermat's Principle and follows the shortest optical path given by the product of physical length and the refractive index. In metamaterials, though, one can craft the nanoscale spatial distribution of the refractive index in almost any desired way, and thus the flow of light can be molded with subwavelength precision. Far-fetched as it may appear, general relatively can actually be put to practical use in a number of novel optical devices based on transformation optics. Guiding how: Using metamaterials, the space for light can be curved in a pre-designed and well-controlled way. A myriad of fascinating devices are achievable using transformation optics and metamaterials. One of the most exciting applications is an electromagnetic cloak that can bend light around itself, similar to the flow of water around a stone, making visible both the cloak and an object hidden inside.

Another exciting example is a flat hyperlens that can magnify the small nanometer-scale features of an object that cannot be resolved with conventional optics. This would revolutionize the field of optical imaging, for instance, because such a metalens could become a standard add-on tool for microscopes. By enabling nanoscale resolution in optical microscopy, metamaterial-based transformation optics could allow one to literally see extremely small objects with the eye, including biological cells, viruses, and possibly even DNA molecules. So that is the end of my prepared statement.

MS. KYZER: Excellent. Well, we'll go ahead and again go down the line. Christian, do you have a question to start us out?

Q Thanks, Dr. Hammond, for joining us. This is a fascinating subject. And, admittedly, I'm not a scientist so I don't understand what meta and nano and all that kind of stuff means necessarily. But if I were -- pretend I'm a soldier, you know, a specialist or a sergeant or a lieutenant, what does this mean for me? What does this science mean in terms of how I operate my equipment and, you know, my personal clothing and all that sort of stuff?

MR. HAMMOND: Okay. First, the word "nano" means it's something smaller than the wavelength of light. And "metamaterials" just basically means it's something that we make and nature doesn't make. So let's look at one of the examples I just gave. If you're out on the battlefield and you see a cloud coming, or you suspect there might be an aerosol chemical or biological warfare being used against you, it's very difficult to quickly detect what the material is. It might take a series of chemical tests or take a while to figure out what the stuff is. Usually this stuff is smaller than the wavelength of light, which means we can't see it. That's what's in all the textbooks on optical physics. However, with these metamaterials, these new materials, we can actually see things smaller than the wavelength of light. This is an enormous breakthrough. We've never been able to do this. If you make a lens with glass or something like that, you're limited to seeing things only the wavelength of light or bigger. The wavelength of light is about half a micron. A micron is one-millionth of a meter.

Now, many pathogens and viruses are much smaller than that and there's no way to see them, but with this hyperlens you can see them. So this would be an enormous -- an enormous improvement, and not just on the battlefield, but it would allow us to make all kinds of materials, what we call, well, nanomanufacturing, which could go into electronic and optical devices that you'd use, from night vision goggles to distance sensors to other kinds of sensors. So I think there would be a boatload of applications to the soldier.

Q Okay, and for the electromagnetic cloak, is that something that could be used for a vehicle-sized object or a person?

MR. HAMMOND: In principle, it can be used for anything, even a building. Of course, obviously the bigger the object, the more difficult it would be to make, at least now. But, yeah, it could be used for anything. What we have demonstrated in the lab is that it works for a cylindrical symmetry, meaning as long as you're looking like at eye level along the ground, it can be cloaked. And we've demonstrated that only at microwave frequencies, which is like radar a little bit. So we still have the problem of how do you cloak it from above -- in other words, from all directions? So research needs to be done, but we have demonstrated what I call the cylindrical case, so that cylinder could go around a person, a tank, a building. Now, this is very -- cloaking is very down the line. There's a lot of issues that we have to solve before we can do it, but the proof of principle has been done, this experiment I mentioned with microwaves. So it's extremely exciting. This experiment was performed in 2006 and it was almost like a chain reaction. The field of transformation optics and metamaterials and negative index materials exploded with this. But, as I say, the proof of principle has a long way to go before we can see that on the battlefield.

Q Okay, great. Thanks.

MR. HAMMOND: Yeah, sure.

MS. KYZER: Okay, David, do you have a question?

Q Yeah, absolutely I do. Hi, this is David Axe with War is Boring.

MR. HAMMOND: Hi, David.

Q Hi. This stuff is exciting, but without understanding most of what you said, it seems to me like there is about a billion obstacles to making this, you know, practically, militarily useful.

So just ballpark it: How long are we looking at until there's like a real practical military application -- in other words, something that somebody can wear or shoot or -- you know, some practical application?

MR. HAMMOND: Okay, well, what we call the superlens -- it goes under different names, but I was describing that with ordinary optics we can't see anything smaller than half a micron, and there's a lot of things we'd like to see. I've already started an STTR. That's like an SBIR -- short business innovative research -- with a company in Indiana, working with Purdue, and they're developing a lens now -- they're in the middle of this project -- that could see pathogens as small as one-tenth of the wavelength of light. And the idea is if you can make this metamaterial that allows for this amazing possibility, all you'd really have to do is like slap it on an existing lens of a microscope and all of a sudden you've increased this resolution by perhaps a factor of 10.

So, this is close. And there are a couple of obstacles to making this real practical, but most of the obstacles we've overcome already. So one of the obstacles, by the way, is loss. When you make these materials, some of the energy, some of the light energy, is dissipated or lost by the material, but that's an active research project and we're trying to figure out how to put what we call gain into the material so, like an amplifier, we can get back the light we lose. So in this respect, David, I think we're -- I can't tell you two years from now we'll have a commercial product, but the STTR program only lasts about three years. There's a first half a year and then there's two years, and then they go on to phase three, where they actually begin to develop something. So, I mean, that's -- in a couple years hopefully we'll be transitioning something to production by a company.

Now, so that, you know, is perhaps the most near term of all. Other things in the nitty-gritty optoelectronic -- in the circuits where you have to use these tiny little components, we could be seeing progress there also in a couple of years. But for the cloaking, there you're right. I don't know if there's a billion obstacles, but there's a lot, and that would be many years down the road. But the thing is, we are not only focusing on that; we're doing a lot of different things, and as you research one area that may be practical in a year or two, then that kind of -- like a tide coming in, you know, it lifts all the boats. You know, it makes progress in all the fields, even these more futuristic fields like cloaking. Q Okay, great. Thanks.

MR. HAMMOND: Sure.

MS. KYZER: And, Grim, do you have a question?

Q Yes, ma'am. Doctor, when you talk about metamaterials, I'm not quite sure if I'm understanding that the light-ending -- for lack of a better word -- properties, are these properties that the materials themselves have, or do they require a power source? Is it something they can do or something they always do?

MR. HAMMOND: That's a good question. Should I just call you Grim?

Q That's fine,

MR. HAMMOND: Okay. It's a property of the material. Now, when I'm talking about metamaterials, most materials that occur in nature are uniform. There may be some impurities or so forth, but basically how the material exists at one point is the same a half a millimeter away and it's the same a half a millimeter away. It's a uniform material. That's how glass or silicon or whatever it is -- that's how nature makes things. It makes them uniform; it makes them the same. A metamaterial we build, layer by layer, almost molecule by molecule so that we can change it, so that instead of having -- the analogy would be this: Imagine a trampoline that's perfectly flat; it's the same everywhere. That's glass or silicon or any of the materials we use, and light would go across like a marble, rolling across the trampoline, straight as an arrow. Now, a metamaterial, imagine this trampoline has curves all over the place, curves designed by the engineer or by the physicist, and these curves will -- and then you freeze the trampoline in this shape. Then you roll the marble. It will go in some wild path, bending and rolling and dipping and twisting all across. And that's a metamaterial, this changing material. But the point in this analogy is we can control the bends in the trampoline, and we design those bends so that the marble goes exactly where we want it to go. Instead of letting nature tell us where the light shall go, as in the uniform materials, we tell the light where to go by designing the material. You could think of it as, in a more realistic sense, to get away from the analogy, is we control the density of the material as a function of position, so that we can make light go in almost any direction we want, and we could do far, far more things that way than using nature's given materials.

Q So, in order to make something like a cloaking -- well, like a cloak work in the field, you wouldn't require a power source in the field. Once it's made, it will have the properties and it will just do it.

MR. HAMMOND: That's the ultimate goal, yes, and that was the second part of your question I did not address, but earlier I said there's this issue of loss. And one way to overcome loss is to feed in energy, and so that would require somewhat of an active material. But, hopefully, using what we call photonic materials, where the loss is very, very small, and in the case of the microscope lens and so forth, we expect that -- we hope to overcome this problem of loss so that there would be no energy and it would just be fixed -- once it's made it's done and it does what it's supposed to do.

Q Thank you.

MR. HAMMOND: You're welcome.

MS. KYZER: And, Andrew, did you have a question?

Q Absolutely. Yeah, Dr. Andrew Lubin.

MR. HAMMOND: Hi, Andrew.

Q Doctor, actually, you've got kind of a -- this is unusual; say, everybody here has spent considerable time in Iraq, Afghanistan, and Horn of Africa. Everybody has spent a lot of time deployed. This strikes me as -- I'll apologize in advance for my phrasing -- kind of a gillysuit version of Mr. Spock's cloaking device. Is this practical? Can you fight in these things? And how do you drink water and spit and talk and do things like that without giving yourself away?

MR. HAMMOND: Well, first of all, I'd like to emphasize that cloaking is just one of the many applications we're looking at. Let me just briefly say we have something that's, I think, even more exciting, at least in the near term. In a way it's like the anti- cloak. With these metamaterials and transformation optics, you could design like a lens or a cover that will take the sunlight and focus it to a point, no matter where the sun is, and with no moving parts. You know, normally in these solar collectors you have to follow the sun and it takes bulky motors and all kinds of things, but with transformation optics and this kind of -- sometimes we call it the anti-cloak because it does just the opposite. It will take all the light and focus it on the same spot. This cannot be done with any other kind of optics. So that could be used for energy source: charging batteries. You know how important batteries are in the field. I've never been in the field, but I'm told -- you know, I see the numbers, how much the soldier has to carry as far as batteries and the issues and so forth.

And in addition to that, this anti-cloak could increase the sensitivity enormously. Since it gathers a much broader spectrum of light, it could make detection much, much better, and you could see things from a farther distance. So I'm going to answer your question now about the cloaking, but I just want to point out, this field in general, I think, will have many applications that will be useful for the boots on the ground kind of thing. But remember, we do the 6-1 research, and it takes a few years and then it's transferred to 6-2 and then -- it does take time to get to the soldiers; there's no question about that.

Now, back to the cloak. There are restrictions. The biggest restriction of all is if light can't get in, then you can't see. So you're blind in there. So that's why cloaking might be -- one of the -- if you ever saw the movie or read the book "The Invisible Man," there's always the question of how in the world did he see? From a theoretical physics point of view, he can't. So that's an issue. There might have to be auxiliary sensors. Now, can he move around? Well, that would be the next step, a conformal cloak, a cloak that could be molded to a body. But that's even more difficult, and, you know, that's very futuristic, but the fundamental ideas are that it can be done.

So there would be restrictions, and let me tell you the biggest restriction that we have now about cloaking, and that's something that we call bandwidth. And all that means is there's infrared light; there's visible light, from red, green, and blue; there's a little bit of UV, and so forth, and the biggest problem we have is to cloak something in all those regions. The experiment I mentioned before was performed in microwaves. Now, suppose we can cloak something in the IR; well, then it would be visible in the visible region. So that's another issue. So as far as cloaking goes, you know, you're partially right; that's going to be quite a bunch more research before it's practical, but if you had an installation that's fixed, like a building or a tank or something, and you wanted to get behind a cloaking region, that's feasible.

Q But then you've got to cloak his M-16 also.

MR. HAMMOND: Oh, yeah, yeah. Well, remember, the way the cloak works is -- well, if it's a fixed cloak, you would -- anything within that cloaking region -- the cylinder let's say -- would be invisible, whether it be a gun or bullets or anything, water and everything.

Q Okay, thank you. So I'll just pass it back to you.

MR. HAMMOND: Sure.

MS. KYZER: Great. Well, we'll go down the line for any follow- ups or additional questions. Christian, did you have any more questions?

Q Yeah, I have a follow up. And I know -- you sound like you're closer to an actual product in the optics thing, but obviously, you know, those of us who have been in the field are sort of excited about this idea of an invisibility sort of cloak deal, so I'm sorry that we're sort of focusing on that, but I'd like to ask you --

MR. HAMMOND: No, that's fine. I understand. I'm just trying to give you the perspective of where things are. And, actually, it's really good for me to get your questions because, you know, ultimately our research is for the soldier, so I'm happy to respond.

Q Okay, well, absolutely, and all these other applications are fascinating. I'd never heard of any of this, and I'm sure our readers will be into it, but if there was one or maybe two things that you could overcome to get a much more rapid fielding date or material or device for fielding on this cloaking thing, what would it be? What's your biggest couple hurdles there?

MR. HAMMOND: The biggest single hurdle is making the material. As I said before, we have to make them almost atom by atom or molecule by molecule. Now, in reality it's more like layer by layer. And since you know, since molecules are so small, it takes a long time. Now, it's not quite that bad. I mean, it's really like maybe thousands of molecules at a time, but it's the manufacturing of the materials. Now, in the microwave region, it's easier because the wavelength is the order of -- well, let's talk about -- yeah, microwaves. The wavelength is about a centimeter or two, and therefore the size you have to make things, it changes the order of the centimeter. That's relatively big and it's easy to do, but when you're talking about light, visible light, you're at half a micron, which is -- a micron, again, is a millionth of a meter or a thousandth of a millimeter, so that the main problem is to be able to develop these materials and change the index as we want at such a small scale. The theory is there. That's the good part. So now it's the manufacturing of these materials.

Q Oh, okay. Interesting. Thanks.

MR. HAMMOND: You're welcome.

MS. KYZER: Great. And, David?

Q Hi. No, I don't have any more follow ups, thank you.

MS. KYZER: Okay, Grim?

Q Just one. I think I understand this already, but I just want to verify. You're talking about, in terms of bandwidth, being able to do this with a number of different kinds of waves. Does that include radar waves?

MR. HAMMOND: Yes.

Q Thank you.

MR. HAMMOND: Yeah, and as a matter of fact, one of the early applications might be to shield from radar. I mean, radar is pretty much a given -- you know, it's a fixed wavelength. So if you want to design something for a given wavelength, then it's a lot easier. And you could say, okay, at this -- we're going to make the material so that at this particular wavelength it's cloaking. So, I mean, that might be -- and even you might be able to go with what I call the conformal type material, something that you can actually spread across the object, but that's a bigger step. But the point is, radar, if you're at a given frequency, that helps a lot. That make the problem much, much easier. The hard problem is to cloak across the entire spectrum. Now, sometimes you might not have to cloak across the entire spectrum for certain applications, but, I mean, the big -- the big goal is to cloak across the visible spectrum because that's where people see, and if you cloak across the visible spectrum, then you'd be invisible.

Q Thank you very much.

MR. HAMMOND: You're welcome.

MS. KYZER: And, Andrew, any more questions? Q Yes, I do, Doctor. Does it strike you that sometimes the Army is overly -- is using technology too much? These young men go in the field -- and this is for the benefit of the boots on the ground -- and when technology doesn't work -- it rips, the sun is not out, a cloud comes over, you fight at night -- they spend more time learning technology than basic warfighting, and too many times when technology fails, these young men and women are killed because they haven't been trained on the basics. Isn't this a major problem with a possible invention like this?

MR. HAMMOND: There's always a problem, yes, of high technology failing, and I'm not oblivious to that. For example, I manage the Photonics Center at West Point, at the U.S. Military Academy at West Point, and it's a relatively small program -- $250,000 a year -- but the point -- one of the main points is we try to get as many cadets through that as possible so that they have hands-on experience with optical equipment. So as the -- at least the officers then will have much better training and will have seen this stuff and understand how it works, and they can then, in turn, explain to the enlisted people the basics of what's going on. So we are, in part, trying to improve the soldiers' background by education.

Now, the second thing is the goal is to make the product, the eventual research, very robust. Like, say, for example, your sunglasses; they, in the windblown sand, are all scratched up, so we developed this polymer -- I say "we" -- not in physics; this is over in chemistry -- but, you know, you brush it on and then it like fixes the problem. And so we are aware of some of the problems on the ground and we try our best, but sometimes we just can't make it as robust as we'd like. And our goal is if it helps the soldier in any way, then we think we're doing good.

So, to answer your question, you have, obviously, a good point, and it's something that we are aware of, and it's something that we try to improve whenever we can, but we don't always make -- I agree with you that we don't always make things as robust as needed in the field, but we're trying.

Q   But it's not even a question of being robust. You look at the -- going back to March 2003, the Jessica Lynch debacle with the 507th maintenance unit. The captain who was in charge, the reason he was in the wrong place at the wrong time, he didn't know how to work his GPS. He loaded the wrong coordinates in. That's basic -- you buy them at Radio Shack. And if that how high tech gets poorly adopted, then I see all sorts of problems coming down the road.

MR. HAMMOND: Yep. Well, I didn't realize that was the issue there, but, I mean, I think to a degree, soldiers will have to learn, will have to advance. I mean, the whole notion of asymmetric warfare is based either on numbers or on technology, and it's technology that can ultimately save lives, whether it be the robotics, the unmanned vehicles that are used all the time. These do save lives, but the price you pay -- I guess nothing is free, you know. The price you pay   is you have to be a little bit more technologically savvy. So I think the answer is twofold. On the research side, we have to make these things easy to use, and on the soldiers' side, it is incumbent upon them to learn how to use these things, just like they learned how to use the M-16. I mean, they take it apart and all that. Well, now there's another thing; they have to learn how to use GPS or whatever.

Q   Okay, fair enough. Thank you.

MR. HAMMOND: Okay.

MS. KYZER: Great. Any other follow ups?

Q   Yeah, I have a quick one.

MS. KYZER: Go ahead.

Q Christian Lowe, Military.com. Dr. Hammond, one quick follow up here. What sorts of universities and other outside research places are you working with on this kind of stuff?

MR. HAMMOND: The lead university on this is Purdue.

Q Okay.

MR. HAMMOND: And they're working with the University of Berkeley, the University of Colorado, and Princeton University. So those universities made up the core of what we call a MURI, a multi- university research initiative. And this is a million dollars a year for three years for three years, plus a two-year option. And it's a nice program and we're hoping that a lot of good stuff will come out of it. So, anyway, those are the universities. There's other universities working on this, but those are the ones I'm managing.

Q Sure. Okay. Thanks a lot.

MR. HAMMOND: Yeah, sure.

Q Hey, and thanks for a great interview.

MR. HAMMOND: Oh, yeah, thanks. It was fun.

Q Yeah, Doctor, by the way, the guys from Berkeley were on TV this morning, on CNN.

MR. HAMMOND: Oh, were they? Thanks. Yeah, they've been making a lot of news lately.

MS. KYZER: Great. Well, we're very glad that we were able to get Dr. Hammond on the line, and thank you so much for your time, again. It was a great discussion. Thank you, everyone, for your thoughtful questions, and I'm certain that we'll be seeing a lot more of this research coming out in the future. But this basically concludes the Bloggers' Roundtable. You can check out the transcript or audio feed at defenselink.mil/blogger. And thank you again for joining us, and thank you, Dr. Hammond, for your time.

MR. HAMMOND: You're welcome. It was fun.

Q Dr. thanks so much.

Q Thank you.

MR. HAMMOND: You're welcome. Thank you, guys. Okay, bye.

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